RCA III

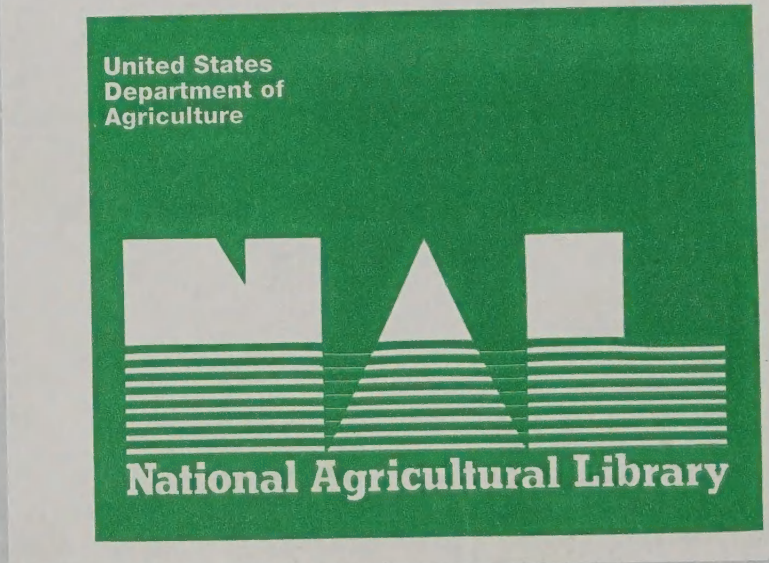
Influence of Social Trends
on Agricultural Natural Resources

MEGATRENDS

Banking and Finance — Biotechnology

Working Paper No. 19C

RCA III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This is part of a set of papers originally presented at the Symposium on
INFLUENCE OF SOCIAL TRENDS ON AGRICULTURAL NATURAL RESOURCES
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(May 31–June 2, 1995, Washington, D.C.)
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Overview of the Symposium

The symposium on *Influence of Social Trends on Agricultural Natural Resources* took place on May 31–June 2, 1995. The speakers presented current trends and were challenged to forecast trends in conservation of our natural resources at two separate points in time—10 and 50 years in the future. This type of forecasting was an unusual challenge to the participants. Many of the "empirically oriented" social scientists chose to remain close to their data, while others did as they were asked and tried to act as seers. Only time will tell how close they came to predicting future scenarios. Assembling any group of scholars will lead to mixed forecasts. Rather than repeat each author's message, we have tried to emphasize some common themes in the presentations. If you want to find out what the authors themselves think, read the papers. It is well worth the effort.

Although the attitudes of the public and the agricultural community differ on some issues, support for a clean agricultural environment is almost universal. The public is concerned for the safety of food and water supplies. The public also feels that laws on threatened and endangered species and wetlands are just right or have not gone far enough in providing protection. Most farmers and ranchers, along with the public, support a federal role in agricultural conservation, especially in incentive payments to promote conservation.

Most of the public would like to see federal spending on agricultural conservation increase or remain the same. The desire of the public and agricultural communities to have an incentive-based system has been partly realized with the passage of the 1985, 1990, and 1996 Farm Bills (respectively Food Security Act of 1985; Food, Agriculture, Conservation, and Trade Act of 1990; and Federal Agriculture Improvement and Reform Act of 1996). Concurrently, the public supports regulation, fines, and withholding government benefits when voluntary conservation is not working. A majority view among presenters was that with time there would be an expanded regulatory role for all levels of government vis-à-vis production agriculture. There was some disagreement on whether this expanded regulatory role would come through the use of centralized, command-and-control regulations or through the use of market-based incentives.

When given an opportunity to voice their opinions regarding conservation compliance, most farmers with highly erodible land supported the program and did not want Congress to abolish it when crafting the 1996 Farm Bill. Furthermore, farmers with highly erodible land and conservation compliance plans believed that NRCS was more than fair in its implementation of conservation compliance planning. Over the last 5 years (the period during which farmers had to acquire their plans and have them fully implemented), farmers have been consistent in their support of the program. However, there is a troubling drop in the percentage of farmers with conservation compliance plans who believe that monitoring and enforcement are being carried out in such a way that farmers who are out of compliance will be found out and will lose eligibility for USDA program benefits.

The environment and ecosystem management will remain important future issues for the public and agricultural producers. During the next 50 years, as the global population continues to grow, agricultural producers and agribusinesses will be challenged to expand food production and the processing and distribution systems to keep pace with population growth without endangering the ecosystems supporting production agriculture. In industrialized countries, alternative food sources will be developed, environmental monitoring will become more widespread and more precise, and new environmentally benign methods of production agriculture and food processing will be developed. Given capital limitations, resource constraints, and increasing demand for food, the poorer countries will face growing environmental challenges as they use their physical resources more intensively in the effort to feed their populations and expand their trade abroad. Sources of environmental stress will be in the energy, manufacturing, and extractive industries in addition to agriculture. The future of humanity will depend on the development and sharing of appropriate technologies and mobilizing global efforts to effectively control population, produce enough food and fiber, and protect the environment.

A number of papers underscored the structural transformation underway in the agricultural and financial sectors. Increased vertical integration and the separation of land and resource ownership for farm operations are rapidly changing the character of agriculture. For example, one author suggested that in the 1980s banking and finance became more national, if not global, as local banks and credit unions—especially in rural areas—went out of business. The cold dollars-and-cents business world of finance merges uncomfortably with the inherent instability of agriculture and the accompanying fluctuations of farm income. During the next 10 years, income in the agricultural sector may be even more volatile, due to the elimination of the farm income safety net. With the gradual removal of this safety net through the 1996 Farm Bill, farmers will face increased financial risk and greater uncertainty. A challenge for operators will be the development of strategies for shifting the increased risk from themselves to others.

One consequence of the consolidation within the financial sector will be the shifting of funds away from rural areas and the increased reliance of farmers on capital and operating loans coming more from commodity processors and input suppliers than from traditional banking sources. Corporations will begin to own more agricultural land, and for the land they do not own, they will contract with farmers as to what to produce and how to produce it in exchange for a guaranteed market for the commodity. In many instances, the farmers will be no more than salaried workers. One impact of these changes will be to make farmers dependent on agribusinesses. Farmers and farm managers will have a vested interest in production, not conservation. In this transformed world of agriculture, a major challenge will be the public sector's voice demanding food safety, environmental quality, and worker health and safety.

Much of the livestock industry—cattle, chickens, hogs, turkeys, and sheep—is currently controlled by a few companies. In addition to livestock conglomerates, industrial consolida-

tions of port facilities and feed, elevator, milling, and soybean-crushing plants limit market access for individual producers. Companies that contract for agricultural products are not typically held responsible for environmental impacts, while individual producers are. Hence, while agricultural processors will increasingly specify what to produce and how to produce it, the environmental consequences of those specifications will shift to individual producers. However, the public will exert enough pressure so that environmental responsibilities will likely be pinpointed as this type of agricultural concentration increases. Not only will concentration of production and processing take place in the livestock sector, it will also occur with grain and oilseed crops, their processing, and the transportation of all agricultural commodities. Farmers, public interest groups, and government officials are just now becoming aware of the structural changes sweeping over agriculture and of the implications they hold for producers, consumers, and the environment.

Crop biotechnology is not currently and will not in the next 10 years be a significant factor in relation to environmental quality. However, some aspects of agricultural industry are more directly affected by biotechnology than others. For example, the livestock industry has been affected through the development of growth hormones and vaccines for increasing livestock production. In contrast, it is more difficult to manipulate cereal grains through bioengineering technology than was thought at first. In fact, these common grains may be easier to modify through conventional breeding techniques that improve multiple genetic (polygenic) traits than by the use of biotechnology, which focuses more easily on single genetic traits.

Crop biotechnology (e.g., herbicide- and pesticide-resistant crop varieties) is following an established technological trajectory rather than defining a new path. Some of these developments feed into existing monocultural practices (with their attendant environmental problems) and limit the use of crop rotations. Mechanization and industrialization are the current dominant trends in agriculture, and biotechnology complements these trends. Biotechnology will have mixed effects on environmental quality, and its impact depends to a great degree on how public policy is implemented in the environmental arena.

Several researchers projected that national conservation institutions over the next decade will remain in place but with reduced funding. State and local institutions will need to significantly increase resources directed toward conservation. Stronger agricultural regulations will be passed at the state and local levels. However, in general, states and local areas do not have the financial capabilities to provide full-service technical assistance and cost-sharing for conservation, nor do they have the staff capabilities to regulate the agricultural industry. In fact, one of the challenges is not only the extent to which states can pass legislation on soil and water conservation but the extent to which they can implement and administer the laws they have. Presenters recommend that state and local political institutions acquire taxing authorities so they can more directly provide staff assistance and incentives to foster natural resource protection and enhancement at the local level. While state and local units of government could assume greater responsibility for soil and water conservation programs,

an important challenge will be how much *both* the agricultural and nonagricultural communities are involved in decisionmaking, as well as how closely local concerns reflect the environmental concerns of the wider community.

The projected unit of analysis for agricultural conservation work is at the watershed level. While this unit may be very appropriate for ecosystem planning (e.g., ecological linkages across a landscape, a context for socioeconomic-political institutions), it presents a number of challenges that have to be addressed if the watershed approach is going to achieve its promise. For example, what is the spatial scale at which a watershed is defined? Is a large-scale or small-scale approach taken to delineate watersheds for planning purposes? Another question is, what criteria are used to separate watersheds: are they biological, social, or topographic in nature? How can watershed planning be reconciled with various overlapping levels of government that have to be coordinated and through which administrative control of conservation policy is exercised? And finally, how can procedural and substantive issues of the wide variety of organizational missions be addressed at a watershed level?

The idea came up repeatedly that while most farmers and ranchers use sound conservation systems, 10 to 15 percent of them are "bad actors." These producers are unaware of or choose to ignore the negative effects of their production systems on the environment. It will be extremely difficult to change the behavior of these people. Participants felt that the larger society will eventually demand that the bad actors be penalized for polluting the environment. The penalties might come as fines, stricter environmental regulation and enforcement, or more programs like conservation compliance. Two forces are at work. First, the structural changes taking place in agriculture are working to destroy the Jeffersonian image of the yeoman farmer that gives farming special status vis-à-vis environmental regulation. Second, more and clearer information about the interaction of production agriculture and environmental quality will result in stronger public demand for environmental protection. Improved resource inventories will facilitate the tracking of environmental degradation and the levying of penalties. Resource inventories will become more important in the future, based on two trends: *increased accountability* for scarce financial resources, and *advancing scientific capabilities* that increase the ability of conservation partners to assess and monitor environmental conditions.

Environmental justice was another topic discussed. Industry and agriculture have taken advantage of minorities by ignoring the effect of agricultural pollutants on minority populations and by placing chemical production, waste facilities, or concentrated farm operations in minority communities. A Presidential Executive Order on Environmental Justice (Executive Order 12898) attempts to address this issue. During the next 10 years, increased awareness of these issues in minority communities will merge with more reliable and accessible information to slow but not stop these negative impacts. The "not in my backyard" movement, a classic middle-class movement, helps to relocate agricultural pollution to minority areas. It will take many years before this entrenched trend is offset.

The future moves erratically, with many choices that each yield unclear results. History has the advantage of being able to look back to add meaning to society's many bends in the road. The exercise of looking ahead 10 and 50 years forces researchers to rely on their basic assumptions about the nature of human beings as well as the influence that systems wield on future events. Skepticism and optimism were the yin and the yang of this symposium. Comparing the present to a future ideal is frustrating because, in some cases, the present environment is toxic to living creatures. However, at the same time, there is room for optimism. The continuing environmental movement in general has been strengthened and sculpted by the legislative and executive branches of different levels of government. This can be attributed to the public's strong support for wetlands, wise use of agrichemicals, food safety, water quality, threatened and endangered species, and safe recreational opportunities. The public also supports localized decisionmaking, which puts human and physical resources in local hands.

As we look 50 years into the future, the trend toward the industrialization of the agricultural sector is bound to accelerate. It seems conservationists are presently pushing their bandwagon down a slight grade because of the public's support. To speed up the wagon, we must institutionalize two new inputs besides the traditional inputs of land, labor, technology, and capital. These added inputs are *environmental considerations* and *fairness/equity*. As these inputs become standard costs for doing business, the agricultural sector will realize its potential to be healthy, fair, and productive.

Frank Clearfield and Steven Kraft

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The Influence of Politics and of Banking and Finance on Agricultural Conservation

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Neither the political process nor financial intermediation typically focuses on conservation impacts as critical factors to be considered when decisions are made. Yet agricultural practices and conservation programs are both defined within a broader context of public policy and the financial intermediation process. Both the political process and financial markets have great importance for conservation practices and how agriculture is practiced. The current set of environmental policies reflects political philosophies concerning the desirability of preserving the natural environment that first became important at the turn of the century and reached a peak in the 1970s. Similarly, the availability of funds and the conditions under which farm loans are made can dictate how individual farmers manage the natural environment.

Political Change

What you see for the future of conservation policy depends very much on how you interpret the election results of November 1994 and the subsequent 6 months of political activity. Personally I do not see them as providing a clear indication that the environmental legislation of the last 30 years, much of which was signed into law by Republican Presidents, will be repealed. My interpretation is that in 1992 the voters felt the Democrats were given the opportunity to govern, and they didn't accomplish anything. In 1994 the Republicans have been given the same mandate. In each case the public was registering a concern with the day-to-day management of the government and was exhibiting a concern with specific instances of government programs being carried to what appear to be perverse outcomes, for example, wetlands regulation.

Despite the rhetoric of the far right, it is not clear that the majority of Americans favor completely abandoning the role of government in managing the environment. Instead, they seem to be looking for ways to make government more effective. This may involve transferring some functions to another level of government, while for others it means finding better ways for the federal government to deliver the service. However, it is clear that for the foreseeable future the focus of political action will be on limiting the authority

of the federal government to manage the environment. Perhaps the best indication of this is the growing emphasis on the Tenth Amendment to the Constitution, which provides for a dominant role for the states.

Financial Evolution

One sector of the economy that underwent major change in the 1980s was finance. Since agricultural finance is a very small part of the national financial market, conditions in agricultural finance are largely determined by national financial trends. In the 1980s, capital markets became global in scope and a host of new types of financial instruments were introduced to provide new investment and financing opportunities. As a result, financial institutions found themselves under great pressure to adapt to new forms of competition and to new demands for their services.

Like the rest of the finance sector, rural financial institutions underwent major changes in the 1980s. The main effect was to integrate rural markets more strongly into the national and international markets. Prior to the 1980s rural financial markets had operated in considerable isolation. Rural and urban markets were segmented in terms of both the demand and the supply of capital. A fragmented banking system, limited geographic markets, and the predominance of small business with limited borrowing opportunities had resulted in only limited integration of rural areas into national capital markets.

There is some question whether the effects of financial deregulation and the subsequent re-regulation have left rural institutions on a level playing field. The effect seems to have resulted in a financial intermediary structure where institutions of different size are governed by different rules. Large money-center banks appear to receive greater flexibility in meeting regulatory standards than do smaller banks. The "too big to fail" syndrome seems to be applicable to banking regulation. Small rural banks are closed even where they may be the only bank in the community, since the national implications are minuscule. However, large urban institutions remain open and are assisted in recovering, even though there are numerous alternative sources of financial intermediation. The effect of the differing policies is in a sense a ratification of behavior in urban areas that is not allowed in rural areas. It has been argued that this leads to an unfair advantage for large banks that contributes to the ongoing process of consolidation.

Rural capital markets are inherently high cost. Loans tend to be relatively small compared to those made in urban areas, and this results in relatively high processing and service charges per dollar loaned. In addition, rural lenders are relatively high cost operations for anything other than routine activities, since they lack the expertise and size to efficiently conduct many types of transactions and appraise unusual loan requests. Finally, lending in rural areas may result in higher loss exposure. Lending for specialized buildings or equipment may be more risky, because the resale value of the collateral, if the enterprise fails, is likely to be less in a rural than in an urban area.

Each of these features will continue to be present in the future. Consequently, farmers' access to financial capital in any form will depend upon the level of return and risk in agriculture compared to other investment opportunities. If agriculture is perceived as a risky sector, then agricultural investments will have to generate a higher rate of return than safer investments outside agriculture or they will not receive funds. To the extent that deregulation has eliminated a pool of low-cost capital in rural areas, farmers, as well as other rural borrowers, will face higher costs. This could lead to pressure to curtail practices that protect the environment in a search for short-term profits.

Although the structure of agriculture is evolving, the process is unlikely to reduce the need for infusions of financial capital from outside the sector. Physical capital will continue to be substituted for labor in farming, particularly as labor becomes relatively scarce in the next decade. Further, as long as farming remains organized primarily on the basis of a family-owned enterprise it will continue to need long-term debt to finance the intergenerational transfer of the enterprise. Finally, irrespective of how farming is organized, it will always require significant initial outlays on inputs that are only repaid after a period of time at the end of the production cycle.

Increased instability of farm income in the future and a continuing need for new investments to maintain productivity, make the farm sector dependent on a stable source of finance if it is to continue to contribute fully to the American economy. Recent changes in financial markets may have the effect of disrupting the flow of funds to agriculture at times when short-term returns appear to be higher elsewhere.

There are two parts to the balance of my discussion. The first is a medium-term 10-year projection and the second a purely hypothetical 50-year guess. Within each I first look at the influence of politics on natural resource use in agriculture and then at the changing role of finance and banking. While I treat each piece separately, they do intersect. At various times financial conditions drive political change, while at other times political forces compel changes in the behavior of financial intermediaries. Over the last 10 years we have witnessed considerable change in how agriculture is influenced by both the political process and by financial markets. In developing a 10-year scenario it is relatively easy to project the implications of continuing along current trends. What is less clear is what might be a reasonable scenario 50 years from now.

The Ten-Year Scenario

Politics

There is little evidence to suggest that the end of the current trend in public policy has occurred. This suggests that there will be further pressure to reduce the federal role in society and we can expect to see ongoing efforts to reduce federal regulations, federal programs and the general influence of the federal government. For agriculture, this is likely

to mean a significant scaling back of commodity and credit programs and a reduction in other forms of federal assistance including food aid and commodity export programs.

Not only will the loss of these programs be important in terms of increasing income instability for farmers, but it will lead to the end of cross-compliance as farmers choose to opt out of federal programs. Without the ability to tie environmental stewardship to federal payments, one of the major means for influencing how farmers use their resources will disappear.

A conservative political climate and Congressional redistricting will have created a body of legislators that is less likely to be receptive to traditional farm interests than in earlier times. Tax cuts and spending cuts will have to come from somebody's hide, and farm programs remain obvious candidates, despite the relatively small amount of money involved. After maintaining disproportionate political power for more than four decades, farmers will finally lose the ability to protect themselves at the taxpayers' expense. By 2005 we should expect to see very little of the existing farm program structure, and more importantly a repeal of the 1949 permanent legislation which currently acts as a club to force the current Farm Bill process to completion.

Grazing fees on federal lands will likely be set by market forces and the water allocation policies of the Department of the Interior will be under great pressure, but a coalition of urban and farm interests in the West should still be able to maintain some federal water subsidies. The effect of any water subsidy reduction will be to shift agricultural production out of the Southwest and back to the central part of the nation where irrigation is not required. The change in the location of production will further increase the instability of supply, because of the unpredictable influence of drought, frosts and floods in this part of the country.

Farmers are likely to have to face market forces with few government programs to protect them. There may no longer be Agriculture Committees in Congress or a Cabinet Secretary of Agriculture, but instead there will be a new department formed by grouping primary industries, all of which are characterized by resource management problems, capital-intensive production, a rural location and limited employment. Agriculture and fisheries have been the slowest to conform to this structure, but we now see increased vertical coordination, the bulk of production occurring on a limited number of large enterprises and the growing use of wage labor. These trends parallel earlier developments in mining and forestry.

Budget pressures remain a second factor driving the reduced role of government. There is little reason to believe that the deficit problem will be resolved by 2005, and it is likely that pressures to trim outlays on marginal programs, like agriculture, will increase as more of the government's resources are shifted to caring for the aging Baby Boom generation as they start to place demands on Social Security.

While agriculture will surely be in a less favored position, it is less clear that the Congress will be unreceptive to environmental interests. It seems to me that even fiscally

and socially conservative suburbanites are concerned about the quality of the environment. They may even be members of wildlife and recreational organizations, whose values are not consistent with those of agricultural producers. One might expect them to favor reducing the direct regulatory role of the federal government, but it is not obvious that they will favor letting farmers do as they please.

Reducing the scope of government intervention in environmental regulation will not reduce the number of controversies. Absent a strong regulatory structure, contentious issues will be pushed into the court system. What may develop is a shift from federal regulation to litigation. The basic question that the courts would have to address is how property rights are to be allocated. Under this scenario, while farmers may be under less pressure to comply with specific legislative rules in using their property, they may find that if their practices result in a problem on someone else's property, then civil law and a property-rights argument can be used against them. Right to farm laws may provide some protection, but as farmers' political influence wanes they are not likely to remain in effect.

It should be noted that while regulations can restrict certain activities, if one is in compliance with the regulations there is often a presumption of acceptable behavior. Thus, where regulations exist, it may be more difficult to mount a civil suit because the presumption is that action that is not prohibited by regulation is permissible. Absent the regulation, that presumption may disappear.

Certainly an obvious consequence of a weaker federal role and stronger authority for the states is the possibility of unharmonized state regulations that can balkanize trade. Evidence of this possibility already exists in air quality standards and food safety regulations. If the federal government abrogates its right to regulate, it is almost certain that states will move into the vacuum. Some states, particularly the wealthier and more urbanized, are likely to impose even stricter rules to restrict environmental degradation.

Even if states do not directly impose rules protecting the environment, the logical consequence of policies that favor local control is a transfer of more power to local government. At this level we may see many urban fringe areas adopt a philosophy that views the natural environment as an amenity that serves the general public. In this political environment landowners may face local zoning rules that preserve "green space" and determine acceptable management practices.

One area where there will certainly be a reduced federal presence is in regulatory policy where legislative authority expires. The most obvious example is the traditional Farm Bill process. Provisions in these bills temporarily override the permanent farm legislation in the Agricultural Act of 1949 for the five crop years. If no action is taken to either extend the provisions of the temporary act or replace it, then when its life ends it is no longer law. Extending an act is a simple decision; all it takes is one sentence in the appropriations bill to continue funding, but without that sentence the legislation expires. While it is clear that the 1949 farm legislation will not be restored, it is less obvious what will happen with other statutes, like the Coastal Zone Management Act, which loses authority in 1995.

Any new legislation is almost certain to place greater stress on reducing the direct role for federal regulation, controlling budget outlays, conducting risk-benefit analysis, and protecting individual rights. To some extent these may be contradictory goals, particularly in the case of environmental legislation. Where property rights are taken, higher levels of compensa-tion may be required, which should reduce the use of unfunded mandates. But, on the other hand, courts may rule against farmers or chemical companies if they perceive that the property rights of others have been violated.

In practice the desire for a reduced federal regulatory role will not have as big an impact as many people assume. This is because the judicial branch will play a large role in determining how far the government can back itself out of responsibility for oversight. Third parties can sue the federal government for failure to enforce statutes, and if they are successful the courts may order the government to do what it doesn't want to do.

It also seems to me the shift in power to environmental interests and health interests and away from producers is not going to be reversed. As noted above, the Congress and the nation are dominated by the suburbs. For many suburban people trade-offs that restrict development and economic activity in rural areas are acceptable, since they bear no direct economic burden and perceive environmental preservation as in their interest.

Banking and Finance

Through the 1980s, while some aspects of the evolutionary change in agriculture accelerated, others slowed or reversed in response to the altered environment. The decline in farm numbers slowed from rates seen in earlier times, despite the financial crisis in the middle of the decade. Concentration in agriculture continued, as the share of production produced by the largest farms increased. A bimodal agricultural structure became an accepted description of U.S. farming.

Large, specialized family-owned enterprises, dependent on large amounts of capital, characterize one segment of farming, while smaller enterprises, making use of limited capital inputs and dependent on a mix of agricultural production and off-farm income, characterize the other main part of the distribution. Mid-sized diversified enterprises relying primarily on farm income, which had constituted the core group of producers in earlier times, continued to decline in numbers. There is little to suggest a reversal of this adjustment.

However, a series of changes in the environment facing agriculture that began in the 1980s and that will evolve in the next decade are likely to affect the shape of the distribution of farms. Perhaps the biggest differences from earlier times that agriculture faced at the start of the 1990s were its greater exposure to risk and the lower level of protection from that risk provided by farm programs. By 2005 the level of risk will be much greater as the safety net of commodity programs is removed.

By 2005 farmers will be unable to rely on the federal government for direct or guaranteed loans, with the possible exception of modest support for minority or beginning farmers. The Farm Credit System (FCS) will likely play a more significant role in commer-

cial lending than it does today as commercial banks withdraw from agriculture to focus on lower-risk ventures. Both the FCS and commercial banks will try to capture as large a share as possible of the "life-style" farms, which will remain the dominant type of farm in terms of numbers. These hobby farms will account for only a small amount of production, but a large share of land, particularly in the vicinity of urban places. Because the owners of these enterprises depend upon off-farm income for their livelihood their land will provide an opportunity for providing significant environmental visual amenities. However, because these are small parcels they are unlikely to allow much public access.

As vertical integration becomes increasingly dominant in the livestock sector and more common in crop production, farmers will rely more on funds from processors than from traditional lenders. Thus, while the aggregate capital needs of agriculture will continue to grow, we will see less of a role for traditional lenders to large producers. At some point the trends in vertical integration will reduce the volume of market transactions to a point where price signals become unreliable. This will further reduce the incentive of lenders to make agricultural loans to producers who do not have long-term contracts with processors.

Resolution of concerns by lenders about legal liability for environmental hazards on property they have repossessed will still remain an issue. The government will have been unable to resolve the conflict between wanting sites cleaned up and the lack of funds in the budget to implement cleanup. This will make lenders more cautious and raise the costs of property inspection when a landowner applies for a loan.

The Fifty-Year Scenario

Politics

By 2045 the United States will be an urban nation. The rural population will be less than 5 percent of the total, and they will be concentrated in the outer hinterland of urban areas. Global population pressure will have made food production a priority, but there will be very few farmers to benefit from the improved market conditions.

The federal lands of the West will have been sold in the early part of the twenty-first century to help retire a portion of the massive federal debt that continued to grow through the last years of the twentieth century. Shortly after the sale, the costs of an unharmonized set of public policies at the state and local level, combined with a major depression brought about by a collapse of confidence in the dollar by foreign holders of U.S. government bonds, will have led to the restoration of a strong federal state.

By 2045 urban interests will dictate how the natural resources of rural areas are to be used. The former Department of Primary Industry has been merged into a Department of the Environment. In the new department, agriculture is a small division of 30 people whose primary responsibility is to monitor environmental impacts of production, particularly the effects on water supplies.

Because North America is one of the few areas in the world where agricultural output exceeds domestic consumption, the production of food and feed is of global importance. However, intensive agriculture will have progressed to a point where significant amounts of what were once cultivated lands in the arid Southwest and most of the erodible parts of the Appalachian and Rocky Mountain areas have been allowed to revert to their natural state. These lands are privately held, but the landowner receives either payments or tax benefits for preserving the environment and allowing public access. Green payments finally arrive.

Financial Intermediaries

In 2045, most agricultural production is controlled by corporate entities and their farms are operated by wage or salaried workers. Corporations view an agricultural division as a useful element in a diversified portfolio of enterprises. Because the risk in farming is relatively uncorrelated with risk in other types of business, there are considerable benefits from this type of diversification strategy.

A small number of very large banks are the main financial intermediaries in the United States, but they have little contact with agriculture. The Farm Credit System has disappeared, in part from a decline in the number of farms and in part from a loss of agency status. Agriculture is financed primarily through equity and debt instruments that are the obligation of parent corporations. The concern with preserving entry into agriculture and the family farm disappeared as the minimum scale for efficient operation increased and lenders became reluctant to advance credit to small producers.

One consequence of corporate large-scale farming is the potential for significant environmental damage if accidents or mistakes occur. Large quantities of potentially hazardous chemicals are concentrated in a small number of locations. Intensive animal agriculture raises the potential for contamination of water from manure discharge. Because there is a separation of ownership and operation, workers have little incentive to undertake careful behavior, particularly if their income is linked to the volume of output. This has led to a revived role for government in regulating management practices.

Even though the nature of agriculture has fundamentally changed, it is still subject to major financial shocks. Excessive optimism about demand and prices still leads to overinvestment and increases in land values. When the expectations are not met the value of farmland falls. But now the consequences are debated in the annual meetings of corporations by their shareholders, rather than in the halls of Congress.

Implications of Biotechnology for Agricultural Natural Resources

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Introduction

Lester Thurow, the Dean of the School of Management at MIT, has been quoted as saying that futurology is what academics do instead of going to a palm reader. Thurow would probably be reinforced in his convictions if he knew about some of the projections that could have been made a decade ago at a meeting like this by persons such as myself. Among the things that would very likely have been said, with little dissent, might have been the following: The ongoing Farm Crisis suggests that there is more need than ever before for a federal commodity program "safety net," since it is clear that the export market cannot be depended on to meet surplus disposal and farm income goals. Among the reasons why this safety net will be needed is the rise of biotechnology, which very shortly will revolutionize agricultural research and agricultural productivity change. The conservation proposals being unveiled for the 1985 Farm Bill (e.g., conservation compliance plan, sodbuster, swampbuster, CRP) are positive steps in the right direction, but they are inadequate to do the job. Strong public support for environmental protection and the growing efficacy of environmental groups in American politics will mean that it is just a matter of time until more comprehensive, far-reaching measures will be incorporated into subsequent farm bills or other federal legislation.[1]

Obviously, much has changed over the past ten years. That we could have been so wrong about such important aspects of agriculture suggests the need for humility as we carry on such an exercise today. By the same token, I still believe there is much value in periodic stock-taking that is based, in part, on a consideration of long-term trends and tendencies. Even so, technological changes and their institutional concomitants are so difficult to predict that this paper will be confined to projections of trends over the next five to ten years and will not attempt to forecast to 2045.

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[1] I have published comments similar to each of these three claims. Citations will be provided, reluctantly, upon request.

The trends identified in the opening paragraph about which we would have been so wrong 10 years ago were not selected at random. Indeed, these trends are precisely the ones that must frame a discussion of the implications of biotechnology for agricultural natural resources in 1995.

In this paper I will make some general observations on the implications of biotechnology for the quality of the agricultural natural-resource base. I will first discuss some historical trends in farm numbers and farm structure, and then make a few observations on the socioeconomic and policy context of agricultural natural-resource conservation. I will then discuss the current status of biotechnology and suggest some possible interpretations of how these new products may affect the agricultural environment.

Before proceeding, however, it will be useful to indicate what is meant by biotechnology. Two important distinctions about biotechnology can be made. First, though I think the distinction is a nonsense, this paper will concern itself with so-called "new" biotechnologies (products made possible through use of the tools of molecular and cell biology such as recombinant DNA, polymerase chain reaction, tissue culture, immobilized enzymes, protoplast fusion, etc.), rather than so-called "old" biotechnologies such as conventional plant breeding.[2] A second, and more important, distinction is between what these "new biotechnology" techniques could be harnessed to accomplish on one hand, and the actual priorities and products to which these techniques have been directed on the other. This second distinction calls attention to the fact that the properties of these techniques are far less important than the institutional structure in shaping the content and consequences of actual technologies.

The Socioeconomic and Policy Context

In his most recent book, *The Age of Extremes* (1994), a panoramic history of the twentieth century, the renowned historian Eric Hobsbawm has provided an impressive survey of the many large-scale, epic social changes that have occurred during this century. It is interesting to note that, in Hobsbawm's view, the one social change that has been swiftest and that has affected the most people has been the dispossession and disappearance of the peasantry and farmers during the three decades after World War II. This change was particularly dramatic in the United States. During the brief 30-year period from 1940 until 1970, there was a loss of nearly 5 million farms (from nearly 7 million farms in 1940 to a little over 2.2 million in

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[2] There are several reasons why treating technologies such as conventional plant breeding as "old" biotechnology is problematic. First, doing so reduces biotechnology to being little more than a metaphorical allusion to agricultural research in general. Second, this characterization ignores the social and biological significance of transgenic and other molecular-level interventions in life forms. Third, implications of the continuity of recombinant DNA with plant breeding ignore the fact that the former tends to involve privatization and commodification of relatively basic or fundamental biological research.

the early 1970s); because of the declining fertility of farm people, the decline of the farm population was even more dramatic.

During the heyday of the post-World War II modernization of American agriculture, from 1950 to the early 1970s, there was a *net loss* of 100,000 or more farms each year. The period of most spectacular decline in farm numbers, 1954–59, witnessed a net loss of about 200,000 farms each year, accounted for by about 200,000 persons entering and 400,000 persons exiting agriculture each year (representing about 4 percent, 4 percent, and 8 percent, respectively, of the approximately 5 million farms that existed in 1954). The decline of farm numbers was largely made possible by mechanization, and thus it is no accident that mechanization was the technological change that featured most prominently in economic and social histories of American agriculture, e.g., Cochrane's (1979) theory of the treadmill of technology.

By the early to mid-1970s, however, farm numbers began to stabilize. From 1974 to 1982, farm numbers exhibited a total net decline of only about 39,000. It was then widely thought that farm numbers had bottomed out indefinitely—that the opportunities for smaller-scale, part-time farming would provide a counterbalance to a slow, but steady rise of large-scale industrial agriculture and of the loss of medium-sized, full-time family farms. It was also reasoned that mechanization of crop cultivation and harvesting had reached its limit, so that it was unlikely that there would be another phase of market-driven farm consolidations and declines in farm numbers made possible through mechanization and Cochrane-style (1979) "cannibalism."

No sooner had farm numbers seemingly stabilized, but several other forces and trends—the mid-1980s farm crisis (Goodman and Redclift, 1989), the decreased rate of entry into farming (Gale 1994), the decreased role of commodity programs (particularly the shrinkage of outlays made possible by the movement of loan rates and target prices toward world market levels), and the extension of the industrialization of animal agriculture from poultry and beef to swine and dairy—unleashed a new phase of farm numbers decline. The net loss of farms was about 153,000 between 1982 and 1987, and there was a net loss of an additional 162,000 farms between 1987 and 1992.

As Gale (1994) has noted, the resumption of farm numbers decline has been largely accounted for by a decreased entry rate, as opposed to being due to the exit rate having increased. During the 1978–82 interval between Censuses of Agriculture, the national entry rate averaged about 101,000 farmers per year. This rate declined during the 1982–87 intercensal period to an average of 75,000 per year, and during 1987–92 to an average of 65,000 annually. Gale attributes much of this shift to the shrinking number of young boys and men in farm families. This shift has also arguably been affected as much or more by the unfavorable outlook for family farming, as research in Wisconsin has revealed (Barham and Wood 1994; Jackson-Smith 1995).

American agriculture is thus poised on the verge of an incipient upheaval. The farm operator population continues to age, rates of entry are declining, farm income is stagnant

and faces decline with the phaseout of commodity programs, animal agriculture is on its way to rapid industrialization, and the full-time family farmer who earns a family living from agriculture and relies primarily on family labor is becoming an increasingly uncommon socioeconomic phenomenon. Interestingly, one of agriculture's primary spheres of renaissance is the growing self-confidence of many farmers in being able to roll back, resist, or circumvent the environmental regulations that many of us thought were a permanent feature of American agriculture just a few years ago.

Trends in Agricultural Resource Management

The recent environmental performance of American agriculture has been a very mixed story. On the positive side, the CRP program has been fairly successful in retiring millions of acres of highly erodible land and in protecting other lands (e.g., grass waterways, filter strips, windbreaks, shelterbelts) that contribute to water quality protection. It has been estimated that "between 1982 to 1992, cropland erosion due to wind and water declined from 3.1 tons per year to 2.1 billion tons per year" (GAO 1995, 22). The cross-compliance program has contributed to conservation tillage now being used on nearly 45 percent of highly erodible lands and nearly 35 percent of non-highly-erodible lands (according to ERS, 1995a, data from their Cropping Practices Survey results). One need only cross the border between northwestern Illinois (where there is a prevalence of cash-cropped corn and high enrollment in federal programs, and the moldboard plow has largely disappeared) and southwestern Wisconsin (where most corn is grown for dairy cattle feed, there is a lower enrollment rate in federal crop programs, and the moldboard plow still dominates in corn tillage) to see the contribution that cross-compliance has made.

It is undeniable that there has been progress in reducing the negative impacts of agriculture on the natural resource base. But there are a number of factors that continue to contribute to agriculture having a negative impact on natural resource quality (see, e.g., Pimentel et al. 1995; CAST 1992; OTA 1990; NRC 1989).

Monoculture and simplification of the agricultural landscape still predominate. For each of the four major field crops in the United States, continuous cropping or continuous row cropping remains the norm. About 83 percent of corn is continuous corn or is grown in continuous row crops (most commonly with soybeans). About 79 percent of soybeans and 89 percent of cotton are continuous-cropped or grown in continuous row crops. About 47 percent of winter wheat is continuous-cropped (ERS 1995a). Continuous cropping and continuous row-cropping are nearly as common on highly erodible land as on other land. In fact, continuous cropping and continuous row-cropping of soybeans were slightly higher on highly erodible land (80 percent) than for all cropland (79 percent). It is widely recognized that monoculture and continuous cropping practices make soil conservation and protection of water quality more difficult.

Agricultural chemical use has increased. Chemical use trended downward after the onset of the mid-1980s farm crisis due to CRP set-asides, the cost-price squeeze, greater awareness that many chemicals (especially fertilizers) had been used at rates considerably above recommendations, the threat or reality of closer or stricter enforcement of water quality rules on nonpoint-source pollution and of various state government regulations of chemical use (e.g., restrictions on atrazine use in certain watersheds in Wisconsin). Expressed in trillion BTU of energy equivalent, fertilizer and pesticide use in U.S. agriculture declined from a high of 988 trillion BTU in 1981 to 773 in 1989. Over the past few years, however, there has been a reversal of the decline of chemical usage, with the energy equivalent consumed as fertilizers and pesticides increasing to 827 trillion BTU by 1992 (ERS 1994). Total nutrient use in U.S. agriculture increased by a dramatic 7 percent from 1993 to 1994, with nitrogen and phosphate usage increasing a staggering 11 percent during this time (ERS 1995b). Nitrogen usage, which was about 12.64 million nutrient tons in 1994, has never been higher. Despite much touting of integrated pest management (IPM) technology, agricultural pesticide usage (as measured by pounds of active ingredients) remains virtually unchanged from the levels of 15 years ago (GAO 1995, 18).

Cultivation of highly erodible land is still widespread. ERS (1995a) data from their Cropping Practices Survey in the major crop-producing states show that about 22 percent of cropland in the major field crops was highly erodible land. There has only been a slight decline (from 30 percent in 1982 to 28 percent in 1992) of the percentage of U.S. cropland that is highly erodible; in some states, particularly those in the Southwest and mid-South, more than 50 percent of cropland acres are still on highly erodible land (GAO 1995, 28).

Agriculture remains the most significant contributor to impairment of the quality of the nation's water resources. About 38 percent of the surveyed miles of rivers and streams, and 44 percent of surveyed lake acres, were estimated to be not fully supporting their intended uses, according to EPA data for 1992 (GAO 1995, 22–23). Agriculture was the leading source of impairment of the quality of water in rivers, streams, and lakes.

The institutional environment will likely be unfavorable for conservation of agricultural natural resources. Emergent institutional changes—the potential demise of the CRP, deregulatory measures such as the current attempt to redefine wetlands, and perhaps most ominously, prospective "property rights" or "takings" laws—will undermine the most important federal programs for protection of agricultural natural resources. Fiscal austerity and the commitment to balance the federal budget will reduce the benefits (price and income supports, crop insurance, FmHA loans, CCC storage payments, CRP payments) that in the past have motivated producers to be willing to submit to the Conservation Compliance Program. The new political climate will make it extremely unlikely that green taxes (CAST 1992) or green payments (Faeth 1995; Smith 1994; Sorenson 1994) programs will be implemented in the foreseeable future. The implementation of trade liberalization measures will introduce more instability in product prices and subject farmers more directly to competi-

tion from low-cost producers in other countries (e.g., Brazil with respect to citrus and soybeans, Argentina with respect to wheat, and New Zealand with respect to dairy).

Agricultural Biotechnology: Promotion, Politicization, and Properties

The Early Development of Agricultural Biotechnology

When Cohen and Boyer discovered the fundamental recombinant DNA (rDNA) process in the early 1970s, they were initially unaware of its commercial potential, and their universities (Stanford and University of California) barely made the one-year deadline for filing of the patent application covering the process. Even so, there was very little commercially-related rDNA research until the late 1970s. It was only when the impulse to regulate rDNA research heated up in Washington, D.C. in the mid-1970s that its practitioners began to give much attention to its commercial potentials. Soon, however, biotechnologists began to promote aggressively the expected benefits of the technology in order to head off mandatory federal regulation. By 1979, there was a significant flow of venture capital into the fledgling biotechnology industry. The enthusiasm about the new technology was so potent that just three years later virtually all major pharmaceutical and chemical companies had biotechnology research programs and there were about 300 small biotechnology start-ups. Most land-grant colleges of agriculture had established biotechnology programs and were beginning to court state legislators to invest more in this promising high-technology (Kenney 1986; Krimsky 1991).

It is useful to go back ten years—the near-term time-frame of the present exercise—and refresh our memories about what was being said about biotechnology at the time. In 1985, the late F. A. Wood (1985), then Dean of Research in the University of Florida's Institute for Food and Agricultural Sciences and Chair of the ESCOP Division of Agriculture's Committee on Biotechnology, wrote approvingly of Jeremy Rifkin's characterization (in *Algeny*, 1983) of biotechnology as being comparable to the discovery of fire by our ancestors in its prospective impact on humanity. "[T]he potential significance of the application of the new biotechnological research techniques," he wrote, "is awesome" (Wood 1985, 137). In Wood's view, biotechnology, through its master process, recombinant DNA, would enable agricultural researchers to transcend the species barrier in the search for useful genes and, in general, would make possible much more direct manipulation of agricultural-genetic information than had previously been possible.

Wood's touting of the revolutionary breakthroughs that biotechnology would make possible in very short order was by no means uncommon at the time. The period shortly prior to the passage of the 1985 Farm Bill was one of very profound hype of biotechnology. Private sector biotechnology boosters sought to attract investors, while public sector boosters strove to increase appropriations from state legislatures, expand federal grant programs, and attract industrial contracts.

By the time Wood had published this paper, biotechnology—particularly agricultural biotechnology—had already generated a considerable opposition. But instead of this opposition causing public and private biotechnology proponents to temper their claims, if anything the hype was intensified in order to demonstrate that the opponents did not have the public interest in mind. Interestingly, the opposition tended to see the breadth and depth of the future impact of biotechnology products on about the same terms as the technology's boosters. Thus, while F. A. Wood was atypical of biotechnology proponents in seeing anything constructive about Jeremy Rifkin's writings, he was perceptive in noting that biotechnology's biggest proponents and opponents had a relatively common view—a revolutionary one—of the likely future impacts of biotechnology.

By the end of the 1980s, however, it was becoming apparent that the boosterism over biotechnology had been premature. After nearly 10 years of R&D, there were essentially no significant agricultural biotechnology products on the market (Buttel 1989). Bovine somatotropin (bST), which had been widely touted as a paradigmatic blockbuster biotechnology, would not be commercialized for another half-decade, and its performance would fall far short of that touted in the mid-1980s (e.g., Kalter 1985; OTA 1986). Agricultural biotechnology stocks were performing poorly. A wave of bankruptcies, mergers, and acquisitions was well underway.

The Progress and Limitations of Biotechnology

In the five years since then, some of the details have changed—about 60 crops have been "engineered," more than 3,000 field tests of transgenic crops have been conducted worldwide, bST has been approved by the FDA and is in the early stages of commercialization in the United States, and the tools of genetic engineering (gene guns, PCR, cloning) have entered widespread use. But little has happened to alter the situation that was becoming clear at the end of the first decade of biotechnology hype: biotechnology was responsible for little alteration of the trajectory of agricultural change other than having become a focal point of its politicization. For the 16th year running, *Bio/Technology*'s (Kidd 1995) illustrative group of 15 agricultural biotechnology companies lost money—a little over $100 million collectively in 1994, with a cumulative total for the group of $3.2 billion in losses.

There are a number of reasons why biotechnology's role in revolutionizing agriculture has been so modest. First, U.S. and world agriculture became progressively more focused on a handful of cereal grains during the second half of the twentieth century. The cereal grains, while relatively easy to manipulate with conventional breeding techniques, are among the more problematic crop plant species to manipulate with rDNA technology and to regenerate whole plants from cells (Chapman 1993). Second, the tools of biotechnology are still largely confined to manipulation of single-gene traits, and virtually all the transgenic crops that have been field tested thus far are varieties than contain one or two single-gene traits. Most major agronomically significant traits (e.g., photosynthetic efficiency, yield, drought

tolerance) are polygenic. It is by no means clear when, or if, biotechnology will be superior to conventional breeding techniques for improving polygenic traits (Schmidt 1995).

The most common traits of genetically engineered crop varieties, accounting for over 95 percent of field-tested varieties (Schmidt 1995) are, in order of importance, herbicide tolerance, insect resistance, virus resistance, and "quality improvements" in identity-preserved varieties. Herbicide-tolerant crop varieties are both the most common type of crop biotechnology product and the most controversial (compare Goldberg et al. 1989 and Fehr 1991; see also Thompson 1994). Biopesticides, particularly insect- and disease-resistant crops (especially use of genes from various strains of Bt to control insects), analogues of naturally occurring insecticidal chemicals such as the neem plant, and insect-virus insecticides are playing an increased role in private biotechnology product lines.

The final major category of genetic-engineering products in crop agriculture is that of identity-preserved varieties, major examples of which are the Flavr-Savr tomato, high-solids tomato, high-laureate canola, and high-oil corn varieties. As long as plant genetic engineering remains largely confined to single-gene traits, identity-preserved crop varieties could become the most significant type of plant biotechnology product (Busch et al. 1991).

Animal biotechnologies have been developed somewhat more rapidly than crop biotechnologies for a variety of reasons. Animal vaccines and other pharmaceuticals are generally closely based on the techniques developed in connection with human pharmaceuticals, and thus benefit from the fact that pharmaceutical R&D spending is many times greater than R&D spending in plant molecular biology. Other animal biotechnologies, such as growth hormones (e.g., bST and pST) and other growth-promoting agents, are essentially very simple analogues of early rDNA discoveries such as genetic engineering of *E. coli* to produce human growth hormone (HGH). (Note that I do not consider animal reproductive technologies such as embryo transfer, twinning, and sexing to be "biotechnologies" because these were mere extensions of ongoing research that preceded the commercialization of rDNA and did not require a molecular-level knowledge base.)

The crop biotechnology products that have been commercialized or are in the pipeline remain *second-order* technologies that are *being adapted to an established trajectory, rather than defining or crystallizing a new one.* This established trajectory in crop agriculture consists of a predominance of farm- and regional-level specialization (monoculture and continuous cropping) along with incremental shifts toward labor-saving technology and larger scales of production. New technologies such as the first generation of biotechnology products provide some useful management tools for dealing with the problems of large-scale, specialized crop agriculture. Herbicide-tolerant crop varieties, for example, may help to rationalize herbicide usage—for example, by expanding the scope of usage of less toxic and/or less persistent herbicides and enabling these crop protection chemicals to be used postemergence. Biopesticide-augmented varieties such as the "NewLeaf" (Monsanto's Bt-modified) potato enable the large commercial potato producer to control Colorado potato beetles without having to resort to crop rotations.

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It is quite possible that the animal growth hormones and other growth-promoting agents will play a role in promoting the industrialization of animal agriculture, particularly by decreasing the viability of family-operated dairy and hog farms in the family farming states of the Northeast, mid-South, Corn Belt, and eastern Great Plains. It should be recognized, however, that these trends were well in motion prior to the commercialization of bST and pST.

This is not to suggest that biotechnology is minor or without consequence. Biotechnology has contributed to a more detailed understanding of many of the genetic and physiological bases of the functioning and improvement of crops and livestock. Biotechnology techniques have made a significant contribution to increasing the efficiency of germplasm evaluation and to improving the production of disease-free planting material of vegetatively-propagated crops. Many new technologies that substitute for agricultural raw materials in the production of industrial goods (e.g., substitution of high-fructose corn syrup and aspartame for sugar) have been directly or indirectly developed through biotechnology (Busch et al. 1991).

The Environmental Controversies over Agricultural Biotechnology

Agricultural biotechnology remains controversial after more than 15 years after the onset of public and private R&D. It is not an exaggeration to say that biotechnology trade magazines remain obsessed with the critics and criticisms of biotechnology—particularly with those critics whose arguments are based on environmental or health "risk" reasoning. Many universities, such as my own, still have staff in their biotechnology centers who work part- or full-time in "biotechnology education," much of which involves surveillance of movements against the technology, and national and international networking about these matters over the Internet.

Agricultural applications of biotechnology account for less than 20 percent of private biotechnology R&D investment, but perhaps 80 percent or more of the conflicts and controversies over the technology have been agriculture-related. A large share of regulatory conflicts and controversies over biotechnology have involved agricultural products—either biotechnology production inputs such as bST, herbicide-tolerant crop varieties, and "ice-minus" bacteria, or food products such as milk produced with the benefit of bST (especially with respect to concern about the antibiotic residues that could result from higher mastitis rates among bST-treated cows) and the Flavr-Savr tomato. It is no accident that most organizations that oppose commercial biotechnology give particular emphasis to agricultural applications because they see genetic engineering of crops, animals, and food to be the most politically vulnerable aspect of biotechnology. The campaigns by the Foundation on Economic Trends and Consumers Union against bST and that of the National Wildlife

examples of groups that have not traditionally emphasized agriculture but which have come to take on agriculture-related biotechnology because of its social salience and vulnerability.

Beginning with their campaigns against field-testing of genetically engineered organisms, which began with the "ice-minus" *Pseudomonas* in the mid-1980s, activism against agricultural biotechnologies has been environmentally related in one way or another. But the proponents of biotechnology have not been content to concede the environmental high ground to the critics. Most major firms in the agricultural biotechnology arena have staked their claims for their biotechnology products, and often their entire approach to product advertising, on appeals to the firms' environmental awareness and the ways in which their products are "green."

Fostering this pro-environmental image for agricultural biotechnology has been a significant challenge because of the prevalence of chemical companies in the industry. Major multinational chemical firms (e.g., DuPont, Monsanto, Ciba-Geigy, Rhone-Poulenc, Hoechst), and biotechnology firms or seed companies with close contractual relations with chemical companies (e.g., contracts relating to herbicide tolerance), are amply represented in the agricultural biotechnology industry. It has thus seemed logical that these companies would be tempted to develop new biotechnology products that would reinforce the sales of proprietary chemicals. Herbicide-tolerant crop varieties have been the key focal point of debate in this regard.

The most common, but least significant, debate over genetically engineered herbicide-tolerant crop varieties has been whether they will mitigate or exacerbate environmental problems through their implications for the amount of herbicides that will be used. The two sides of the debate are familiar, so little will be said about them here. Proponents of herbicide tolerance stress that most varieties have been engineered to be tolerant of newer, low-dosage, nonpersistent chemicals. Herbicide tolerance also enables postemergence use of these chemicals, which will be more efficient and require smaller dosages. Herbicide tolerance can also increase the efficacy of chemical weed control in no-till, soil-conserving production systems (see, e.g., Fehr 1991). Opponents (e.g., Rissler and Mellon 1993; Goldberg et al. 1989) argue that herbicide tolerance will reinforce chemical usage, enable crop plants to tolerate higher and/or more frequent doses of herbicides, and make both pre-emergence and post-emergence applications more routine, thereby increasing herbicide usage. These varieties also involve the risk that herbicide-tolerance DNA may be transferred to wild and weedy relatives, which in turn would render these weeds more difficult to control with herbicides. Both sets of arguments have considerable plausibility, and I think it is likely that effects of each type will be manifest with respect to different crops and regions. Arguably the most significant implication of herbicide-tolerant crop varieties over the long term, however, is that these technologies will be among the cornerstones for rationalizing continuous row-crop monocultures. By this I mean that the viability of continuous row-crop monocultures depends on being able to deal with persistent and resistant weeds. Herbicide-tolerant crop varieties, which will permit post-emergence application of the most popular

and efficacious herbicides, will be a significant management tool for extending the viability of these systems.

There are two quite different environmental criteria for assessment of biotechnology products. One criterion is whether these products would make a positive contribution to an alternative or "sustainable" agriculture. In this regard, there are some biotechnology products that "sustainable farmers" would consider employing, such as viral pesticides or possibly even Bt-modified crop varieties. Sustainable farmers, however, would be more reluctant than most of their conventional counterparts to employ these varieties over large expanses or during several successive growing seasons, because of concerns about developing resistant strains of pests and pathogens. While sustainable farmers generally must depend on private seed firms for their planting materials and have a strong preference for varieties with pest- and pathogen-resistance characteristics, they are not likely to see the new biotechnology varieties as particularly advantageous. Many of the genetically engineered resistance traits, for example, are attractive mainly to monocultural producers for whom particular organisms have become pests because of a lack of landscape diversity and crop rotation. Further, some biotechnology products, e.g., herbicide-tolerant varieties, would be of very little interest to most sustainable farmers. Other biotechnology products, such as animal growth hormones, would be completely proscribed for use on "organic farms."

A second, more general criterion concerns how the new biotechnology products would affect the environmental performance of conventional or mainstream agriculture relative to its mid-1990s baseline. In this regard there are several considerations. One consideration is whether biotechnology products involve "environmental risks or hazards," e.g., transfer of herbicide tolerance to weedy relatives, the widespread development of insect pests resistant to Bt toxins, or the widespread dispersal of pest organisms (e.g., Pimentel et al. 1989). Some of these potential risks—for example, of dispersal of pest organisms in a manner similar to kudzu or gypsy moth—are no doubt very unlikely. Others, such as development of insects resistant to various Bt toxins, are more likely; in fact, it is generally accepted that insect resistance to some Bt toxins has already been detected (Holmes 1993).

In the main, I anticipate that the environmental impacts of biotechnologies seem very likely to be an indeterminate mix of positive and negative consequences relative to the mid-1990s baseline. Individual biotechnologies, as well as the entire set of new biotechnology products, have both positive and negative implications for environmental quality. On one hand, it is important to recognize that the basic thrust of the contemporary private agricultural R&D system is to develop new technologies that will appeal to the "upper end" of producers who constitute the most attractive market segment and who are most willing to pay a premium for high-performance or high-quality products. In general, this will mean that R&D firms will stress the development and commercialization of products that provide useful management options for large-scale, capital-intensive, monocultural/continuous-cropping producers. By the same token, R&D firms recognize that these upper-end customers' enterprises and practices present environmental challenges, and that these

producers and managers will not be interested in new products that involve major environmental or health liabilities.

The environmental implications of biotechnology products are much like those of the mechanization of cultivation. Mechanization of tillage and planting can result in the declining use of physical structures such as shelterbelts and grass waterways—especially if, through public policy, we permit or encourage this to happen. Yet conservation tillage and no-till are also mechanization processes, and crop rotation practices on commercial-scale field crop farms are inconceivable without modern mechanical equipment. The balance of these positive and negative impacts of biotechnology will thus depend on the degree to which public policy requires agricultural production to be environmentally sound.

Concluding Observations

There remains much fascination with how biotechnologies will contribute to a dramatic restructuring of agriculture. To some extent, some biotechnologies will be part of this process, particularly since identity-preserved commodities will tend to be grown under contract, generally on a relatively large scale. But there is little evidence that biotechnology will be chief among the factors that are leading to the "incipient upheaval" in American agriculture referred to earlier. In fact, while I was among those who in the 1980s felt that the sociotechnical dynamism of agriculture would inevitably shift from mechanical to biological technologies, it strikes me that the most critical emergent technologies in agriculture will remain those of large-scale mechanization, especially the mechanization and industrialization of livestock production. In the future, it is possible that further increases in mechanization of livestock production combined with site-specific (or "precision") agriculture will continue the critical role that mechanization has played in the development of twentieth century American agriculture. It is also worth noting that precision agriculture, much like biotechnology, is now being touted as a "green" technology, even though many soil scientists and agronomists familiar with "precision ag" admit that there is no evidence for this claim.

In most respects, biotechnology products have indeterminate implications for the quality of agriculture's natural resources. Whether biotechnology does or does not contribute to conservation of agriculture's natural resources will be shaped by our political and economic institutions. Particularly critical will be the degree to which there is an indefinite rollback in the current public policy structures that provide incentives to resource conservation. If those incentives and regulations are terminated, the consequences for the long-term quality and productivity of agriculture's natural resources will be adverse.

There is, however, one important respect in which biotechnology could have a long-term negative effect on agriculture's natural resources—specifically, through its role in shaping the content of public research. While some of the luster has come off biotechnology research, it remains the case that the dominant thrust of public research today consists of biotechnology. Thus, despite the lip service often given to "sustainable agriculture," the

mechanisms of and priorities for publicly funded agricultural R&D at both the federal and state levels serve to crowd out basic and applied agroecological and sustainable-agriculture research. Although the political signals that are apparent today suggest that agroecological and sustainable-agriculture research is no longer high priority, my guess is that at some point in the not too distant future, American agriculture will be expected to adhere to higher environmental standards than those in effect today.

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